

# Astrophysics



**NAC Astrophysics Subcommittee**

NASA Headquarters

March 15, 2016

**Paul Hertz**

Director, Astrophysics Division

Science Mission Directorate

[@PHertzNASA](https://twitter.com/PHertzNASA)

# Eyes on Exoplanets Update



The image displays the 'Eyes on Exoplanets' web application interface. The main view shows a star field with a red box highlighting the 'K2 Field'. A red arrow points from this field to a detailed view of a planet, 'HOT JUPITER'. The interface includes a sidebar with 'Kepler Discoveries' information and a bottom status bar showing 'NOW SHOWING 458 PLANETARY SYSTEMS'.

**Kepler Discoveries**

Planet-finding isn't easy – something that initially looks like an exoplanet discovery may turn out to be a false alarm. Because of this, Kepler results are sorted into two categories: confirmed planets and candidate planets. Confirmed planets are Kepler discoveries that have been verified to exist by other instruments, including ground-based telescopes. Candidate planets are likely exoplanet discoveries that have yet to be verified in this way.

**Kepler Discoveries:**

- Confirmed
- Candidates
- Both

**About the Planet**

**HOT JUPITER**

Name: K2-1b  
Parent Star: Red Dwarf  
Discovery Date: 2011  
Mass: 1.04 Jupiter  
Orbital Distance: 0.0124 AU

Orbital radius: 0.0124 AU  
Orbital period: 11.4 days  
Distance from Earth: 124 light years  
Number of Earths that could fit inside: 10,000

Planet size: 1.04 Jupiter  
Discover with: Kepler

Planet type: Hot Jupiter  
Discover with: Kepler

Planet size: 1.04 Jupiter  
Discover with: Kepler

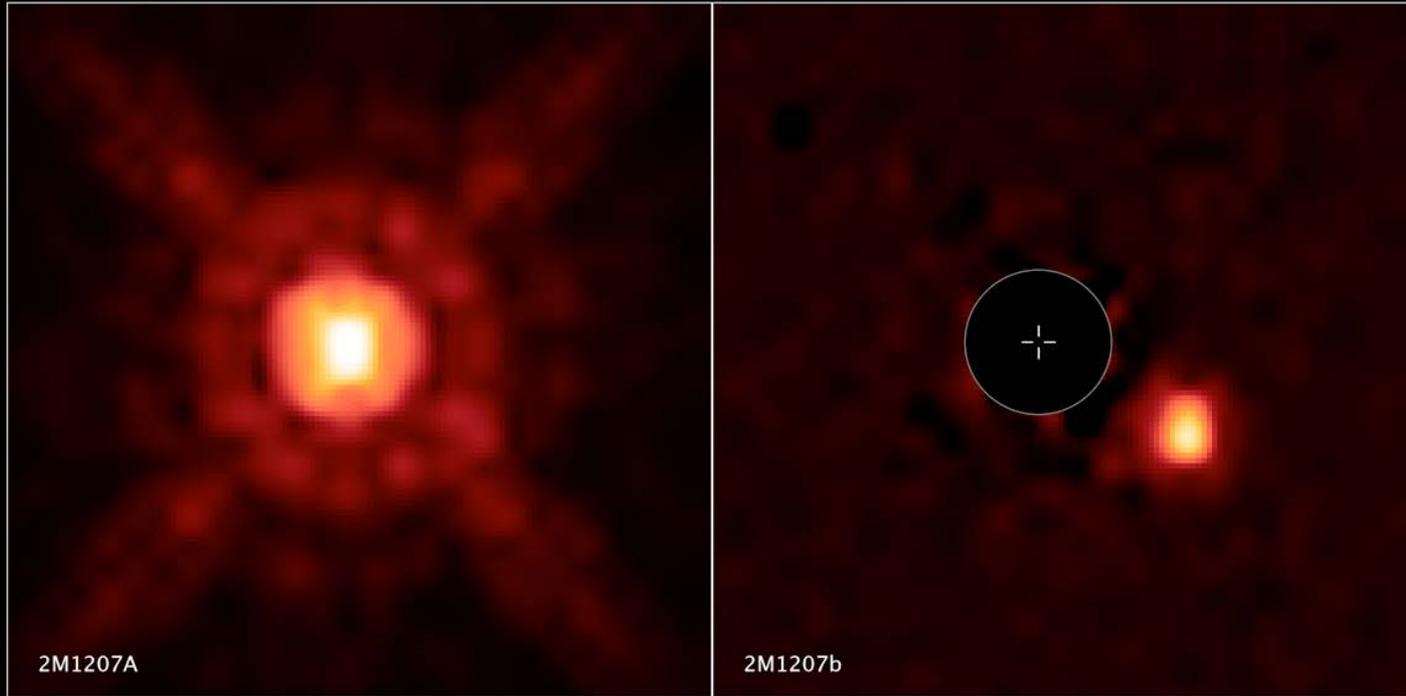
Planet type: Hot Jupiter  
Discover with: Kepler

Approximate visualization

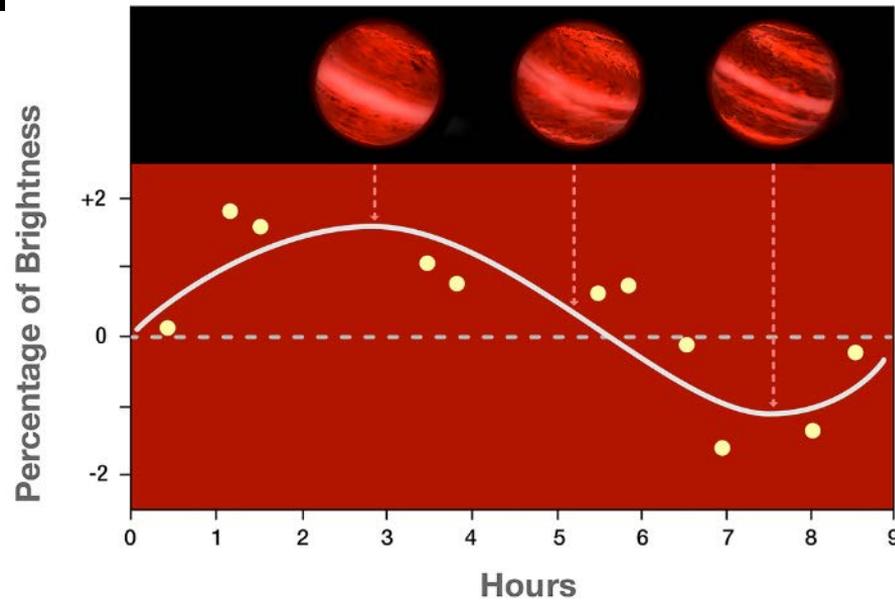
NOW SHOWING 458 PLANETARY SYSTEMS

K2 discoveries now visible in 'Eyes on Exoplanets'

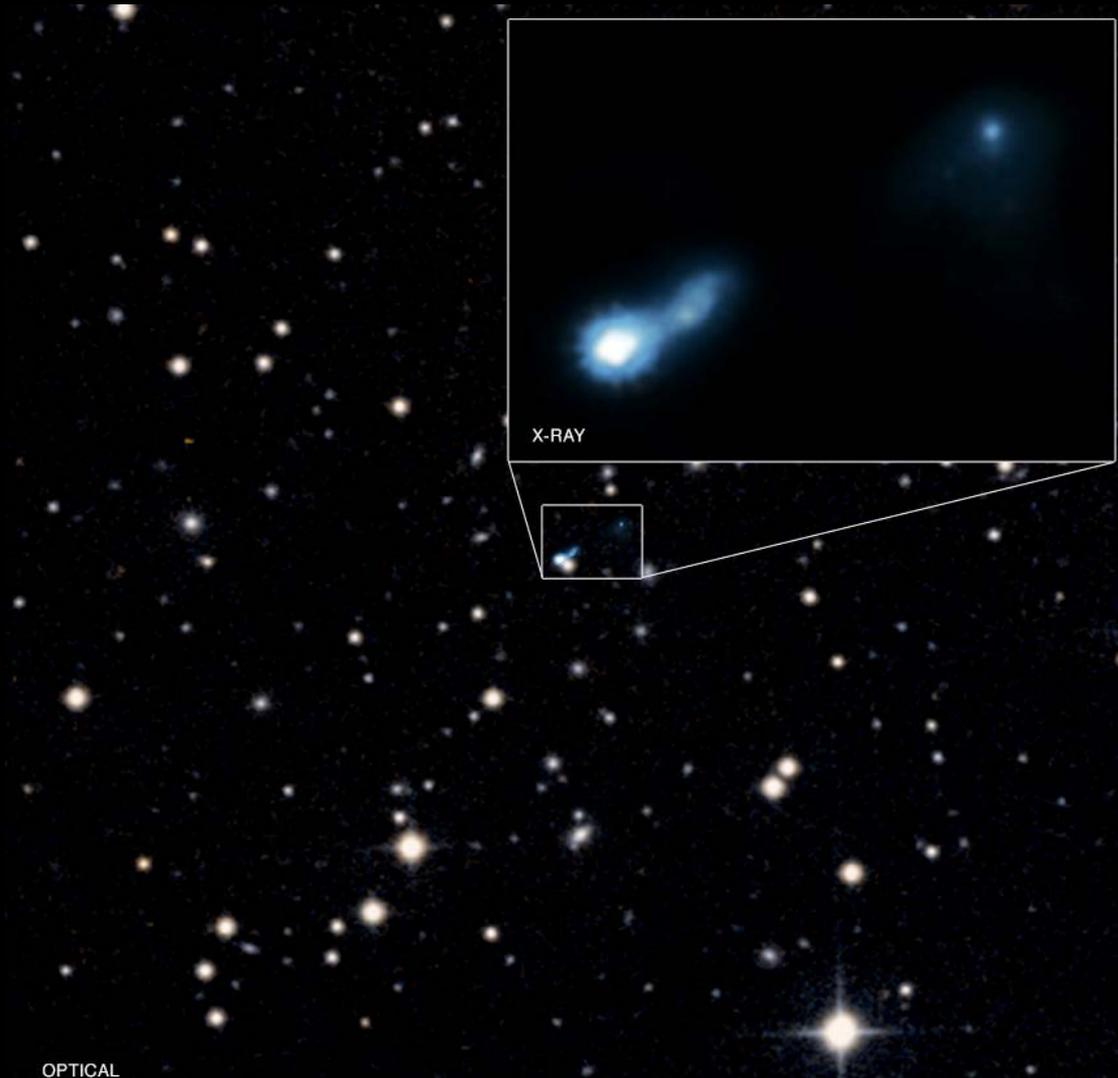
Brown Dwarf 2M1207A and Companion ▪ Hubble Space Telescope WFC3/IR



NASA, ESA, and Y. Zhou (University of Arizona) ▪ STScI-PRC16-05b

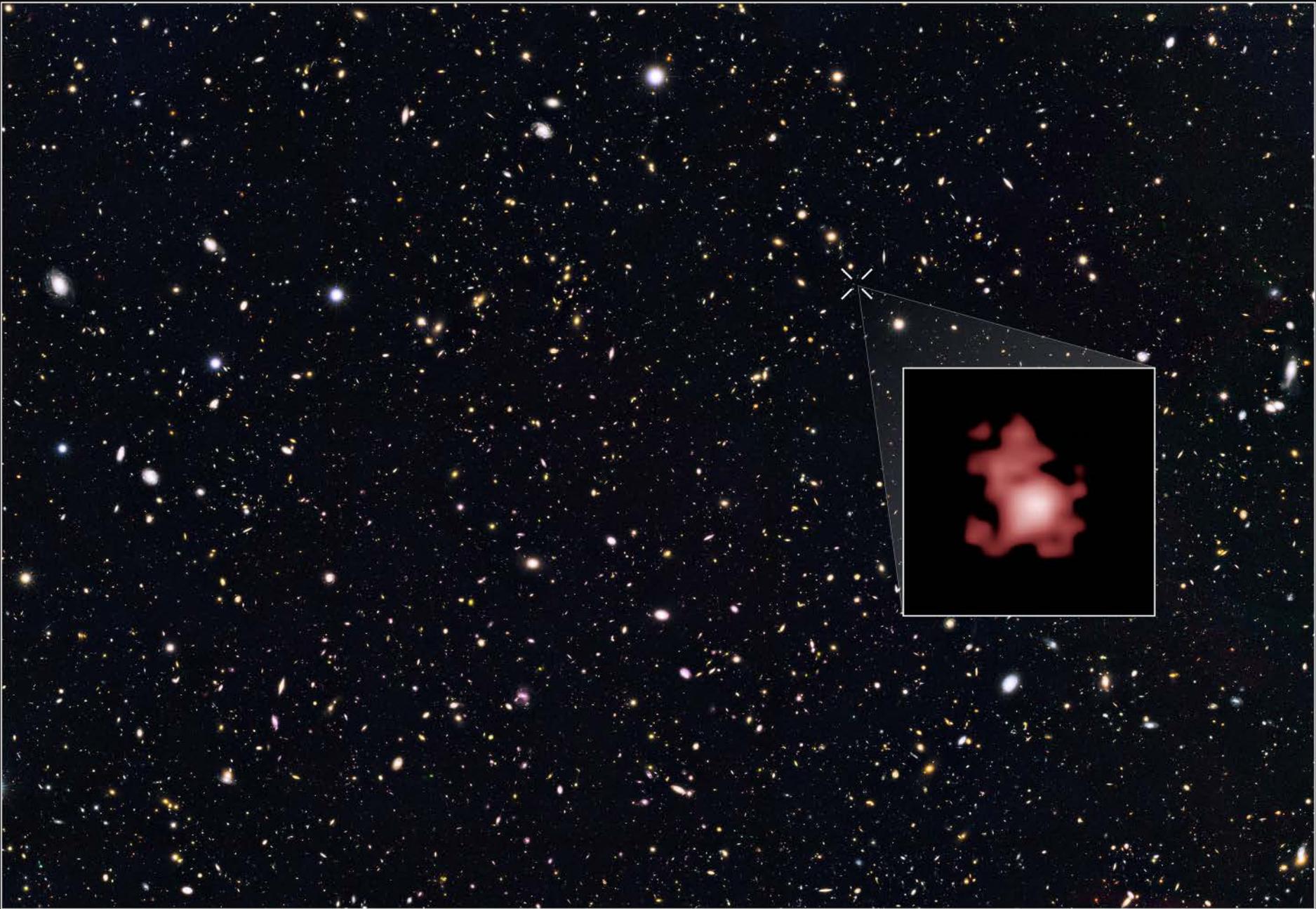


# Glow from the Big Bang Allows Discovery of Distant Black Hole Jet (B3 0727+409)



OPTICAL

Credit: X-ray: NASA/CXC/ISAS/A. Simionescu et al, Optical: DSS



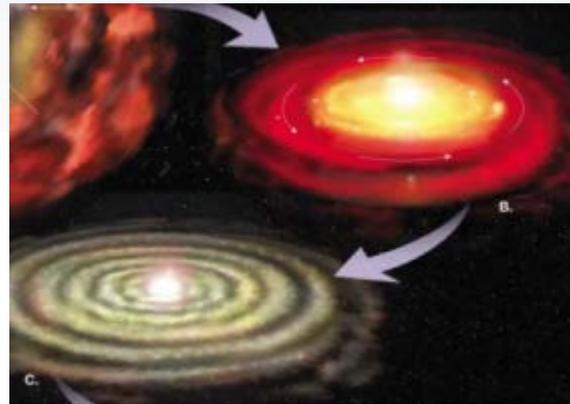
# Why Astrophysics?



**Astrophysics is humankind's scientific endeavor to understand the universe and our place in it.**



1. How did our universe begin and evolve?

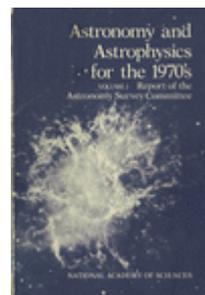


2. How did galaxies, stars, and planets come to be?

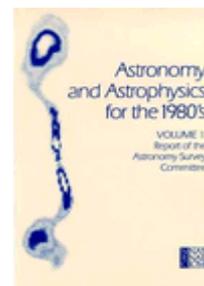


3. Are We Alone?

These national strategic drivers are enduring



1972



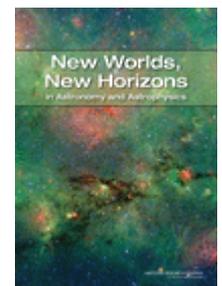
1982



1991

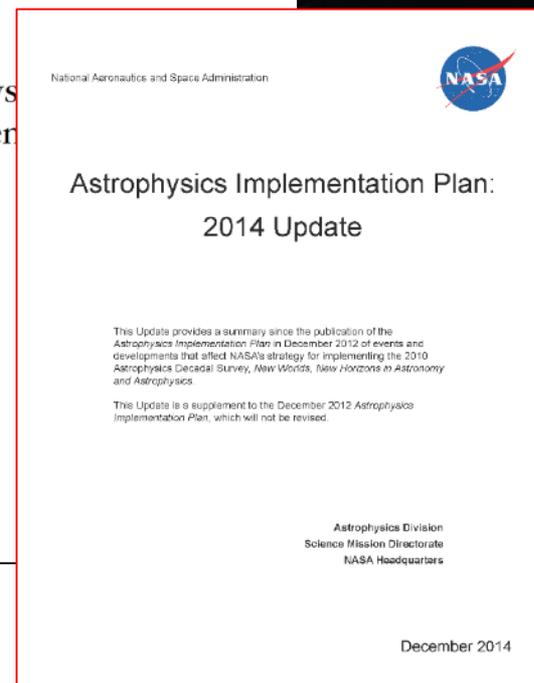
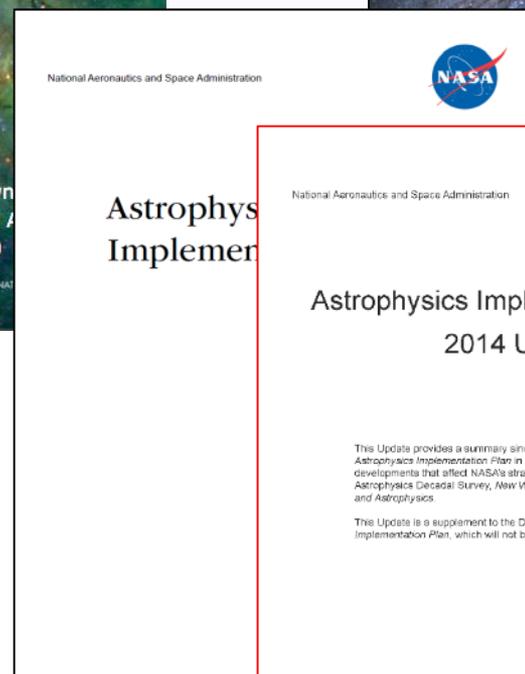
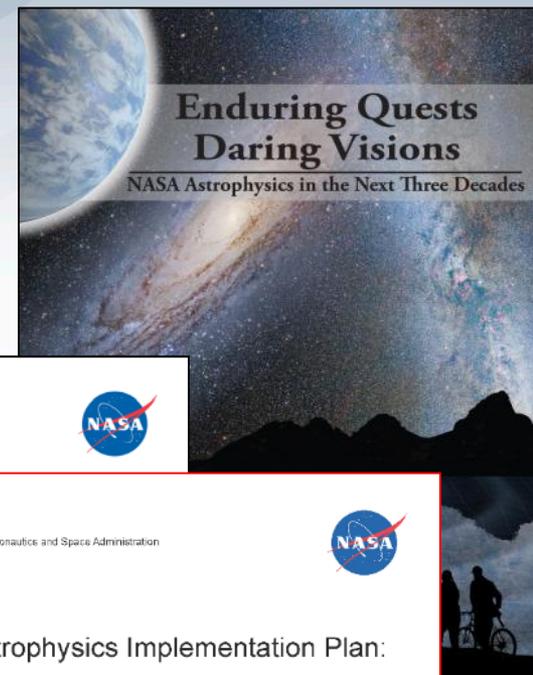
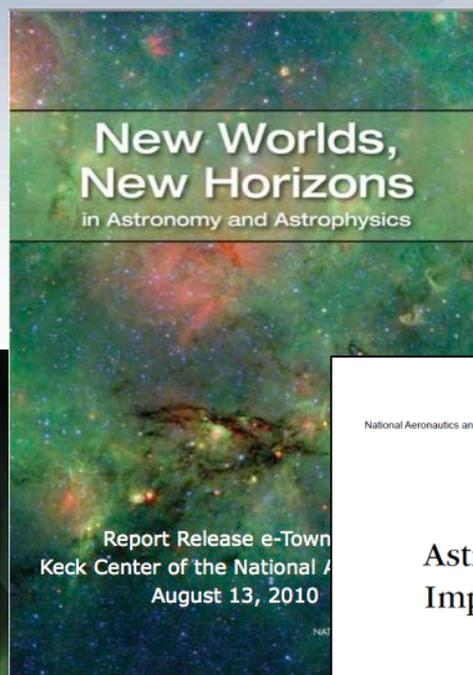
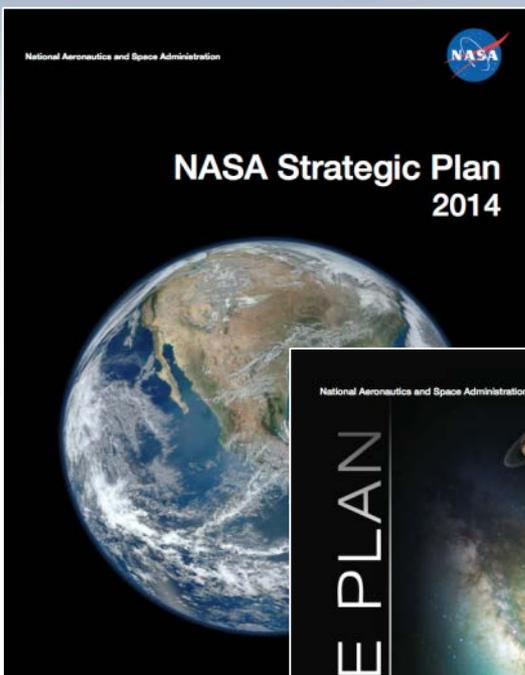


2001



2010

# Astrophysics Driving Documents



<http://science.nasa.gov/astrophysics/documents>

# Astrophysics - Big Picture



- **The FY16 appropriation and FY17 President's budget request provide funding for NASA astrophysics to continue its programs, missions, projects, and supporting research and technology.**
  - The total funding (Astrophysics including JWST excluding STEM) remains at ~\$1.35B.
  - Fully funds JWST to remain on plan for an October 2018 launch.
  - Funds WFIRST formulation (new start) starting in February 2016.
  - Will require some adjustments to FY16 plans in response to appropriation levels.
  - Will require some adjustments to FY17 proposal depending on Senior Review outcome.
- **The operating missions continue to generate important and compelling science results, and new missions are under development for the future.**
  - Chandra, Fermi, Hubble, Kepler/K2, NuSTAR, Spitzer, Swift, ESA's XMM-Newton all operating well; Senior Review is in Spring 2016 for FY17 and beyond.
  - SOFIA is in 5-year prime operations as of May 2014; HAWC+ 2nd generation instrument to begin commissioning in Spring 2016; 3rd generation instrument concept studies selected; Senior Review for SOFIA is in Spring 2018.
  - ESA's LISA Pathfinder successfully launched on December 3, 2015.
  - JAXA's Hitomi (né ASTRO-H) successfully launched on February 17, 2016.
  - Missions under development for launch include NICER (2017), ISS-CREAM (2017), TESS (2017), JWST (2018), ESA's Euclid (2020), WFIRST (mid-2020s).
  - 5 SMEX and MO concept studies selected in 2015; MIDEX AO in 2016; NASA joining ESA's Athena X-ray observatory and ESA's L3 gravitational wave observatory.
- **Progress being made toward recommendations of the 2010 Decadal Survey.**
  - NRC Mid Decade Review (with NSF, DOE) underway; Jackie Hewitt (MIT) is chair; NRC Mid Decade Review committee report expected in May 2016.
  - NASA initiating large mission concept studies as input for 2020 Decadal Survey.

# Proposal Selections Since January 2015

Status: February 25, 2016

	Proposal Due Date	Notify Date	Days past received	Number received	Number selected	% selected
Kepler K2 GO – Cycle 1	Sep 23, 2014	Jan 16, 2015	115	92	36	39%
Swift GI – Cycle 11	Sep 25, 2014	Jan 6, 2015	123	165	39	24%
Roman Tech Fellows	Nov 6, 2014	Feb 3, 2015	89	8	3	38%
NuSTAR GO – Cycle 1	Nov 25, 2014	Apr 17, 2015	143	193	35	18%
Fermi GI – Cycle 8	Jan 22, 2015	June 26, 2015	155	190	36	19%
NESSF-15	Feb 6, 2015	June 2, 2015	116	134	10	7%
Kepler K2 GO – Cycle 2	Feb 27, 2015	June 12, 2015	105	76	35	46%
Chandra GO – Cycle 17	Mar 17, 2015	July 17, 2015	122	582	175	30%
APRA (Basic Research)	Mar 20, 2015	Aug 12, 2015	145	149	40	27%
SAT (Technology)	Mar 20, 2015	Aug 12, 2015	145	27	11	41%
Hubble GO – Cycle 23	Apr 10, 2015	June 24, 2015	75	1114	261	23%
EPDS (Doppler Spectr)	Apr 24, 2015	July 2, 2015	69	6	2	33%
ADAP (Data Analysis)	May 15, 2015	Sep 29, 2015	137	250	51	20%
Exoplanet Research	May 22, 2015	Oct 15, 2015	146	43	7	16%
Kepler K2 GO – Cycle 3	Jul 1, 2015	Oct 14, 2015	105	72	32	44%
SOFIA GI – Cycle 4	Jul 10, 2015	Oct 22, 2015	104	155	82	53%
Spitzer GO – Cycle 12	Sep 11, 2015	Oct 26, 2015	45	104	31	30%
SOFIA 3 <sup>rd</sup> Gen Instrument	Oct 7, 2015	Dec 10, 2015	64	3	2	67%
WFIRST Sci. Inv. Teams	Oct 15, 2015	Dec 18, 2015	64	38	12	32%
Swift GI – Cycle 12	Sep 25, 2015	Jan 19, 2016	116	185	43	23%
NuSTAR GO – Cycle 2	Dec 11, 2015					
Fermi GI – Cycle 9	Jan 22, 2016					

NESSF Presentation  
by Linda Sparke<sup>76</sup><sub>34</sub>(HQ)

100% of 2015 selections announced within 155 days

R&A Selection Rate: 23%; GO Selection Rate: 28%

# 2015-2016 Antarctic LDB Campaign



Gamma-Ray Imager/ Polarimeter  
for Solar flares (GRIPS)

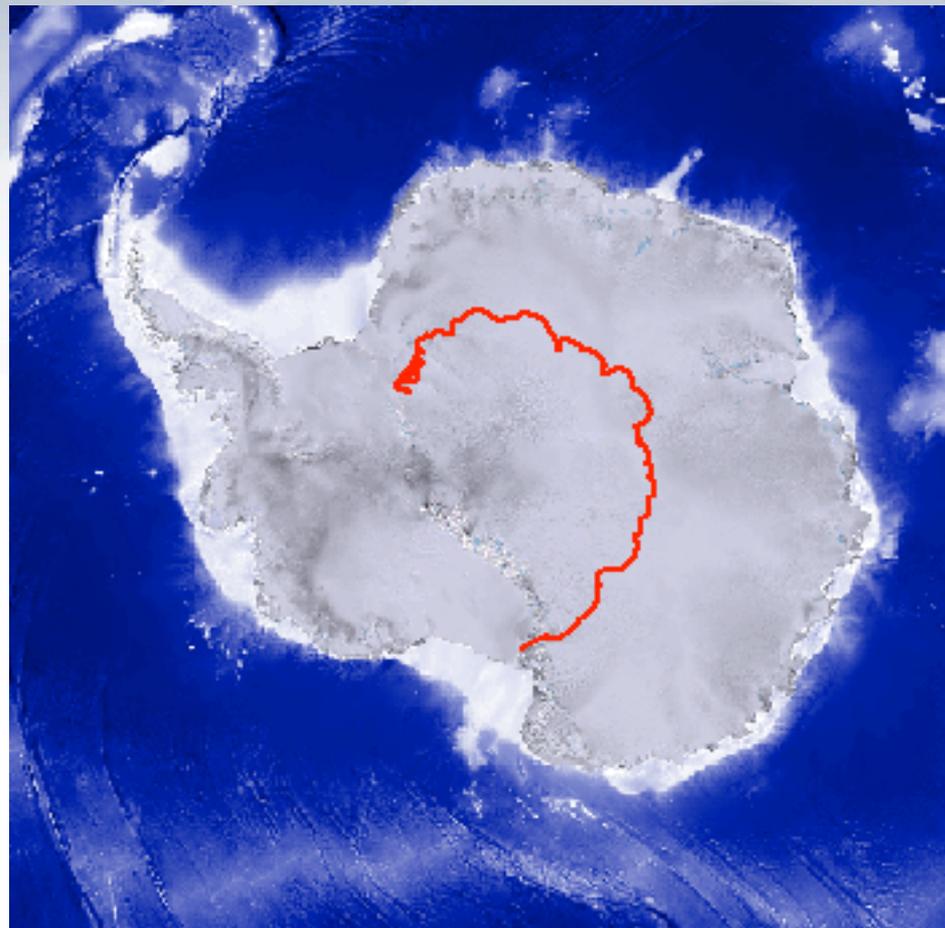
Stratospheric Terahertz  
Observatory (STO-II)

<http://www.nsbf.nasa.gov/>  
<http://www.csbf.nasa.gov/antarctica/ice.htm>

# 2015-2016 Antarctic LDB Campaign



*Gamma-Ray Imager/ Polarimeter  
for Solar flares (GRIPS)*



*Launched January 19, 2016  
Flight successfully completed January 30, 2016  
Data vault and other critical components recovered*

<http://www.nsbfnasa.gov/>  
<http://www.csbf.nasa.gov/antarctica/ice.htm>

# Recent & Upcoming Suborbital Launches

- Fall/Winter FY16 Sounding Rocket Launches @ White Sands NM
  - ✓ Colorado High-resolution Echelle Stellar Spectrograph (CHESS 2); K. France, U. Colorado (Feb 21, 2016)
  - Micro-X; E. Figueroa, Northwestern U. (~Nov 2017)
  - CIBER-2; Bock, Caltech (~Dec 2017)
- Winter FY16 Long Duration Balloon Campaign @ McMurdo Antarctica
  - Stratospheric Terahertz Observatory (STO-II); C. Walker, U. Arizona (Dec 2016)
    - Due to weather, payload will be stored in place to be part of next Antarctica campaign.
- Spring FY16 Ultra Long Duration Balloon Campaign @ Wanaka NZ
  - Compton Spectrometer and Imager (COSI); S. Boggs, U.C. Berkeley (Apr 2016)

CHESS 2



Credit: NASA/WSMR

- CHESS 2 (The Colorado High-resolution Echelle Stellar Spectrograph) sounding rocket experiment facilitates observations of Atomic-to-Molecular transitions phases in translucent clouds for the local Interstellar Medium (ISM) by observing nearby stars that were too bright for Hubble and FUSE.
- Detailed composition and temperature maps at the diffuse/translucent ISM boundary will be possible for the first time with data from CHESS 2.
- The target for CHESS observations is the star Lambda Ori.
- CHESS 2 was launched on a Black Brant 9 from White Sands Missile Range in New Mexico.

# 2016 Senior Review Timeline



Action	Date	Done
Draft Call for Proposals issued	August 20, 2015	✓
Deadline to send comments on draft to NASA	September 10, 2015	✓
Final Call for Proposals issued	September 25, 2015	✓
Senior Review Proposals due	January 22, 2016	✓
Main panel meets in Washington, DC	February 22-25, 2016	✓
HST review and site visit in Baltimore, MD	March 8-10, 2016	✓
CXO review and site visit in Cambridge, MA	March 22-24, 2016	
Delivery of panel reports to NASA HQ	April 2016	
NASA Response/direction to projects. Reports released on APD website.	May-June 2016	

For more information:

<http://science.nasa.gov/astrophysics/2016-senior-review-operating-missions/>

# Explorers MDEX and MO AO in 2016



The target schedule for the solicitation:

Release of draft AO: Spring 2016 (target)

Release of final AO: Late summer 2016 (target)

Proposals due: 90 days after AO release

Selection for 9-month competitive Phase A studies: Summer 2017 (target)

Down-selection: Late 2018 (target)

## MDEX Parameters

PI-managed mission cost cap is \$250M (FY17\$), not including the cost of the Expendable Launch Vehicle (ELV) or any contributions.

Standard launch services on an ELV will be provided for MDEX missions at no charge against the mission cost cap; no MDEX ISS-attached payloads.

MDEX launch readiness date no later than December 2023.

## Mission of Opportunity Parameters

PI-managed mission cost cap is \$70M (FY17\$) for Partner MOs and Small Complete Mission MOs, including ISS-attached payloads.

PI-managed mission cost cap is \$35M (FY17\$) for suborbital-class MO.

Small Complete Mission launch readiness date no later than December 2022.

Partner Mission of Opportunity endorsement need date before January 2022.

Astrophysics Explorer Program planning budget is sufficient to select and execute one MDEX mission and one MO.

<http://explorers.larc.nasa.gov/APMDEX2016/>

# ST-7/LISA Pathfinder

## ST-7/Disturbance Reduction System (DRS)



- ESA Mission with NASA Collaborating
- Project Category: 3 Risk Class: C
- DRS flies on the ESA LISA Pathfinder spacecraft
- Sun-Earth L1 halo orbit
- Drag-free satellite to offset solar pressure
- Payload delivery: July 2009
- Launched: December 3, 2015 GMT
- LPF prime mission: 7 months
- Data Analysis: 12 months

### CURRENT STATUS:

- LISA Pathfinder successfully launched on December 3, 2015.
- Satellite reached Earth-Sun L1 on Jan 22 and all systems are nominal.
- Test masses released on Feb 15 (“Elwood”) and Feb 16 (“Jake”) are operating nominally.
- Began science operations on March 1, 2016.



- ESA’s LISA Test Package for 90 days
- NASA’s Disturbance Reduction System for 90 days
- ESA planning short (2-3 months) mission extension if all goes well

APS Update by  
Ira Thorpe (GSFC)

# NASA's L3 Study



- NASA intends to partner with ESA on the ESA-led L3 gravitational wave mission with launch in 2034. This responds to the recommendations of the 2010 Astrophysics Decadal for a space-based gravitational wave observatory.
- Following the successful launch of the LISA Pathfinder, NASA has formed an L3 Study Team (L3ST) drawing membership from members of the US astrophysics community.
- The goals of the L3ST are:
  1. Analyze the options for NASA participation in the L3 mission and work with the European L3 consortium on proposals to ESA; and
  2. Prepare a report to the 2020 Decadal Survey on NASA's participation, including possible options, in the L3 mission as a minority partner.
- 15 members (plus 6 member technology analysis group). David Shoemaker (MIT) is Chair. ESA has appointed an observer.
- First meeting held February 17, 2016.
- The L3ST Charter and list of selected members can be found at <http://pcos.gsfc.nasa.gov/studies/L3>.

APS Update by  
David Shoemaker (MIT)

# NASA's Plans for a GW Observatory



Implications of the LIGO detection and announcement: it is about funding and priorities and timing.

- Either we do a US-led LISA, or we participate in ESA's L3 gravitational wave observatory. If we do a US-led LISA, then we do it either before or after WFIRST.
  - We are not doing it before WFIRST, because the Decadal Survey said WFIRST was the higher priority.
  - We would not change this unless the 2020 Decadal Survey tells us to do US-led LISA after WFIRST rather than one of the four large mission concepts that we are beginning to study.
  - ESA plans to launch L3 in 2034.
- Possible outcomes from the 2020 Decadal Survey regarding a space based GW observatory.
  - Continue on the path we are on for a 10% share of L3 in 2034.
  - Increase our share to ensure that the third arm is reinstated and that more US technology is included, subject to ESA approval. This would require the Decadal Survey to allocate a medium-size mission priority to a US share in L3. This gets a better L3 at the expense of not doing something else in the NASA portfolio.
- By the time of the 2020 Decadal Survey, we will have:
  - Outcome of LISA Pathfinder (so far so good but not successful yet).
  - Another 4 years of LIGO results to inform our priorities for GW observatories beyond LIGO.

# Hitomi (formerly ASTRO-H)

## Soft X-ray Spectrometer and Soft X-ray Telescope Mirrors



### CURRENT STATUS

The U.S. provided instrument contributions to the JAXA Hitomi mission.

- Soft X-ray telescope mirrors (SXT-S and SXT-I)
  - X-ray Calorimeter Spectrometer Insert (CSI), including Adiabatic Demagnetization Refrigerator (ADR) and ADR Controller
  - Aperture Assembly
  - X-ray Electronics Box (X-box)
  - High Temperature Superconducting Leads
- Successfully launched from Tanegashima Space Center, Hitomi is continuing on-orbit checkout.



- Feb 25 – SXS first light ✓
- Feb 28 – Deployment of extendable optical bench ✓
- Mar 6 – Turn on SXI instrument ✓
- April 8 – Open SXS gate valve
- Early April 2016 (TBC) – NASA Cycle 1 GO call

APS Update by  
Richard Kelley (GSFC)

- **Explorer Mission of Opportunity**
- **PI:** R. Kelley, Goddard Space Flight Center
- **Launch Date:** Feb 17, 2016 on JAXA H-IIA
- **Science Objectives:** Study the physics of cosmic sources via high-resolution X-ray spectroscopy. The SXS enables wide range of physical measurements of sources from stellar coronae to clusters of galaxies.
- **Operations:** Prime Mission is 3 years

<https://heasarc.gsfc.nasa.gov/docs/astroh/>

# SOFIA

## Stratospheric Observatory for Infrared Astronomy



- **World's Largest Airborne Observatory**
- 2.5-meter telescope
- 80/20 Partnership between NASA and the German Aerospace Center (DLR)
- Science Center and Program Management at NASA-Ames Research Center
- Science Flight Operations at NASA-Armstrong Flight Research Center
- Four US and Two German science instruments commissioned
  - Provide imaging, spectroscopy and photometry ranging from visible to far infrared
  - Advanced science instruments under development for future operation

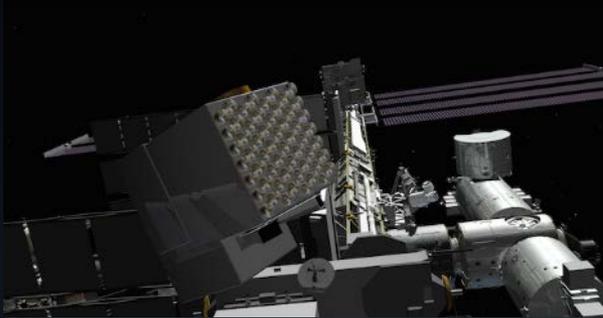
### CURRENT STATUS:

- In the 2<sup>nd</sup> year of prime mission operation
- Observing status:
  - Cycle 4 started in February 2016
  - Occultation data (Cycle 3) synergetic with New Horizons
  - Calibrated data from Horsehead nebula released to the astronomical community in February 2016 with no proprietary restrictions
  - 7-week, 3 science instrument deployment to Christchurch, New Zealand planned from June 4<sup>th</sup> – July 25<sup>th</sup>, 2016
- Second generation instruments:
  - Commissioned upGREAT, multi-pixel heterodyne spectrometer (German instrument)
  - Testing/integrating HAWC+, far infrared imager & polarimeter; 2016 commissioning (U.S. instrument)
- Two Third-generation instruments selected in 2016 for six month study. Down select in November 2016
- Implemented science community feedback and IG recommendations for improved science productivity
  - Large impact science observation program offerings
  - Increased support for guest investigators by a factor of 3
  - Increased capacity to deploy multiple instruments
  - Increased support for future science instrumentation
- Recompeting contract for science mission operations

# Astrophysics Missions in Development

NICER  
NASA Mission

3/2017



Neutron Star Interior  
Composition Explorer

CREAM  
NASA Mission

7/2017



Cosmic Ray Energetics  
And Mass

TESS  
NASA Mission

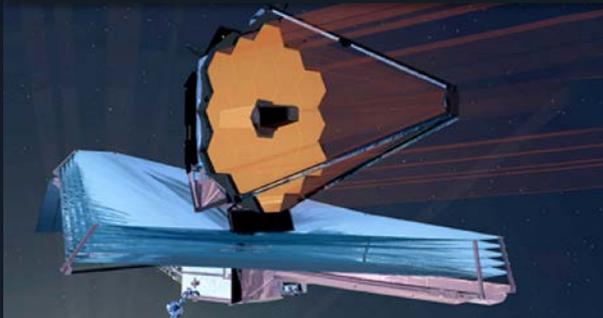
8/2017



Transiting Exoplanet  
Survey Satellite

JWST  
NASA Mission

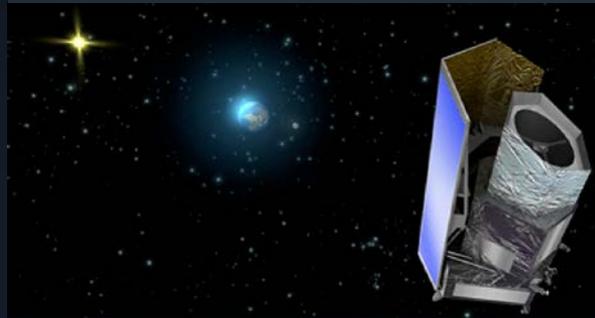
10/2018



James Webb  
Space Telescope

Euclid  
ESA-led Mission

2020



NASA is supplying the NISP  
Sensor Chip System (SCS)

WFIRST  
NASA Mission

Mid 2020s



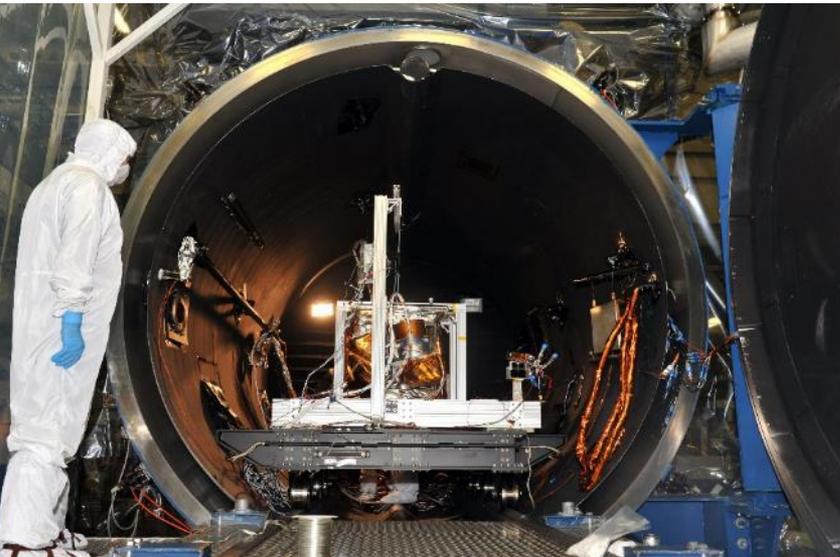
Wide-Field Infrared  
Survey Telescope

# NICER

## Neutron star Interior Composition Explorer



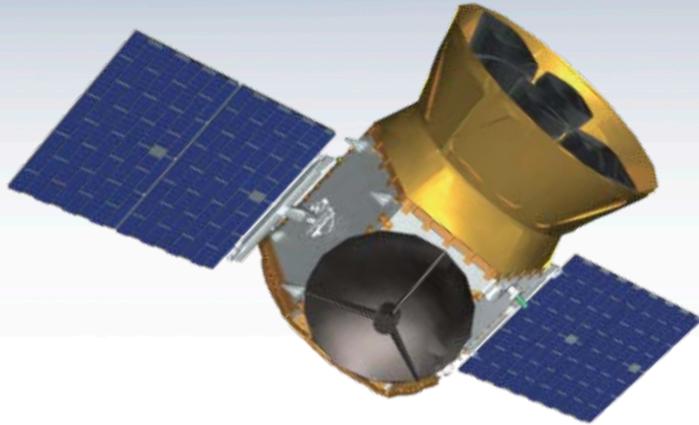
- All subsystems/sub-assemblies have completed fabrication and environmental testing.
- The NICER project has now started final payload integration. ✓
- December 10-11, 2015: Pre-environmental Review ✓
- January 28, 2016: Start Phase D ✓
- February 2016: Start of payload environmental testing
- Payload will be delivered to KSC in July 2016 and stored at KSC until launch.
- March 2017 (TBC): Launch on SpaceX-11 commercial resupply service (CRS) flight to ISS



<https://heasarc.gsfc.nasa.gov/docs/nicer/>

# TESS

## Transiting Exoplanet Survey Satellite



### CURRENT STATUS:

- CDR held Aug 4-7, 2015
- Delta CDR held Dec 7, 2015
- Spacecraft bus structure delivered Feb 2016.
- Instrument Flight Lens delivery Feb/Mar 2016.
- Completed flight instrument lens hood and spacecraft propulsion tank.



*Instrument lens hood*

### Standard Explorer (EX) Mission

**PI:** G. Ricker (MIT)

**Mission:** All-Sky photometric exoplanet mapping mission.

**Science goal:** Search for transiting exoplanets around the nearby, bright stars.

**Instruments:** Four wide field of view (24x24 degrees) CCD cameras with overlapping field of view—operating in the Visible-IR spectrum (0.6-1 micron).

**Operations:** NLT June 2018 launch with a 3-year prime mission including 2 years of spacecraft operations and an additional 1 year ground-based observations and analysis. High-Earth elliptical orbit (17 x 58.7 Earth radii).



*Spacecraft propulsion tank*

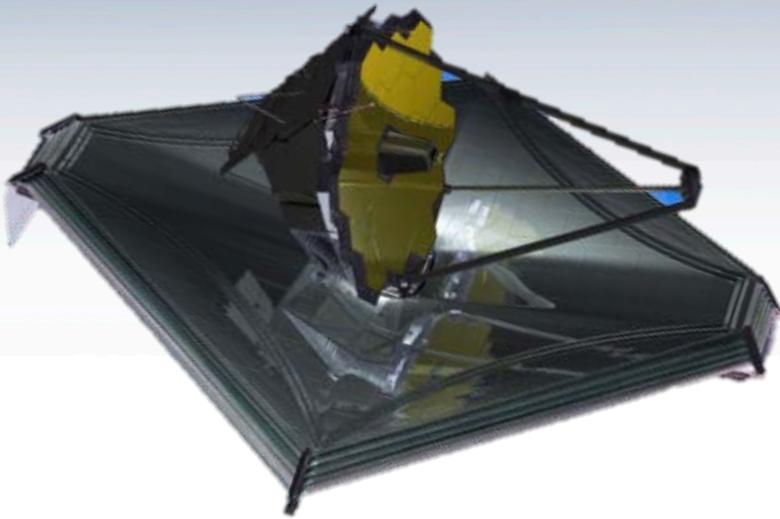
### UPCOMING EVENTS:

- Spring-Summer 2016 - TESS bus integration and instrument integration ongoing.
- Fall 2016-Spring 2017 - TESS Observatory integration and test.
- Fall 2016 - System Integration Review (SIR)
- Fall 2016 - KDP-D
- Summer 2017 - TESS delivery to KSC launch site.

<http://tess.gsfc.nasa.gov/>

# JWST

## James Webb Space Telescope



### Large Infrared Space Observatory

Top priority of 2000 Decadal Survey

**Science themes:** First Light; Assembly of Galaxies; Birth of Stars and Planetary Systems; Planetary Systems and the Origins of Life

**Mission:** 6.5m deployable, segmented telescope at L2, passively cooled to <50K behind a large, deployable sunshield

**Instruments:** Near IR Camera, Near IR Spectrograph, Mid IR Instrument, Near IR Imager and Slitless Spectrograph

**Operations:** 2018 launch for a 5-year prime mission

**Partners:** ESA, CSA

### 2015 Accomplishments

- Completed Telescope Structure
- Completed second Telescope Pathfinder test at JSC
- All updates/fixes made to ISIM following 2<sup>nd</sup> cryovacuum test
- Spacecraft Bus Structure delivered to I&T
- Final ISIM cryovacuum test started
- Mirror installation onto Telescope Structure started

### 2016 Plans

- Complete ISIM cryovacuum testing ✓
- Complete mirror installation ✓
- Install ISIM into Telescope Structure
- Complete Flight Sunshield Membranes
- Conduct final GSE test at JSC before test of Flight telescope and instruments

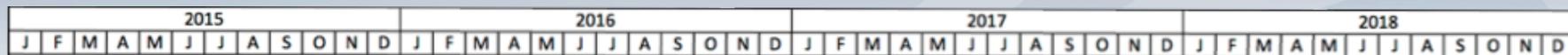
<http://www.jwst.nasa.gov/>

# Changes Since Last Meeting

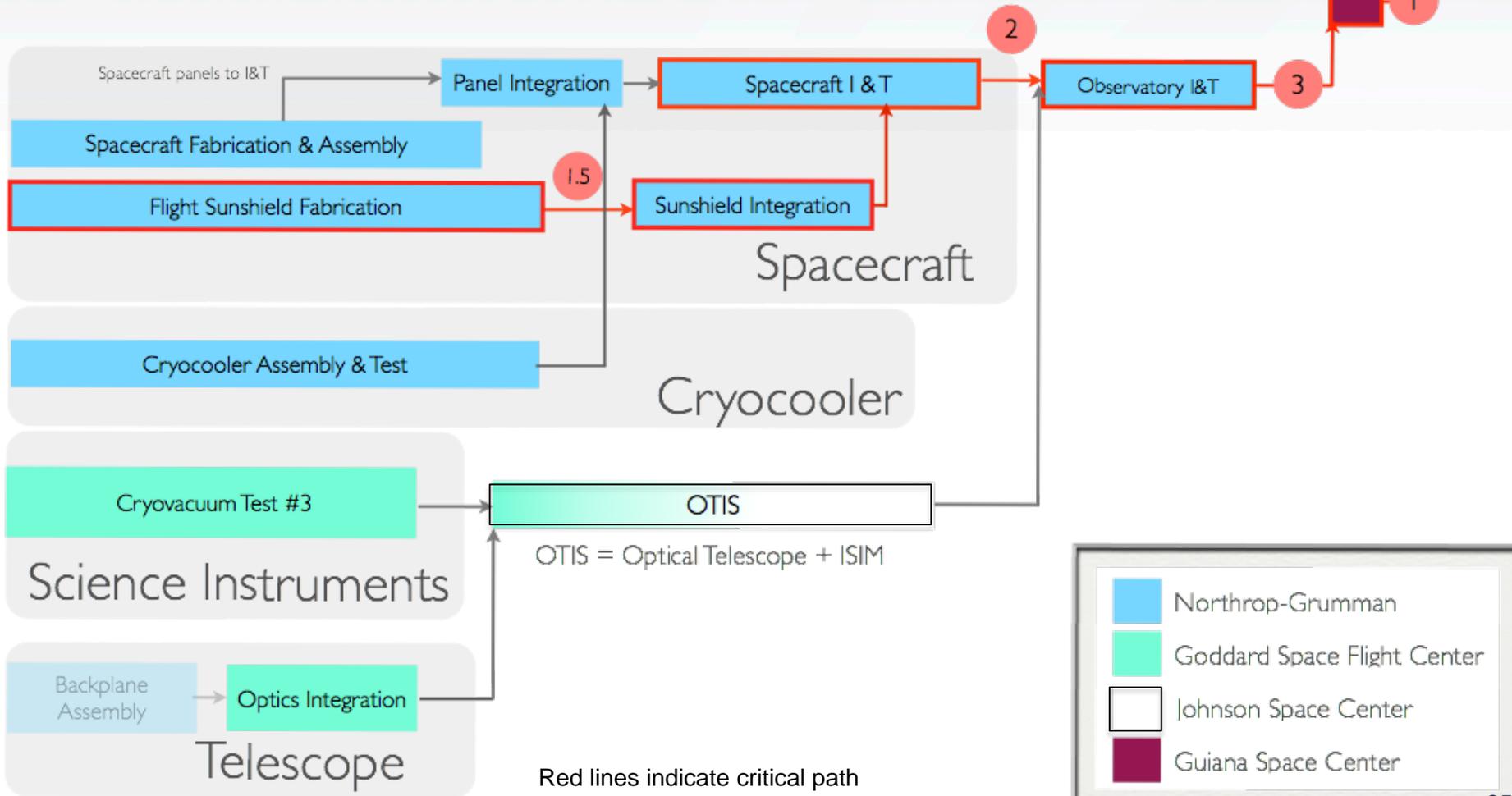


- Working with new GAO examiner team for FY2016 audit.
- ISIM successfully completed its third and final cryovacuum test and is back in the GSFC cleanroom awaiting its next integration steps.
- All primary mirror segments installed onto Telescope Structure, Aft Optics System scheduled to begin this week.
- Optical Ground Support Equipment (OGSE) test #2 analysis completed.
- The "Core2" test hardware is nearly completely assembled at GSFC in preparation for cryo testing this Spring.
- Flight sunshield membrane manufacturing continues. 3 layers still in manufacturing, 2 assembled and shape tested, final membrane seaming completed.
- Significant progress on all other sunshield hardware.
- Redesigned  $\frac{3}{4}$  actuator undergoing final analysis.
- Spacecraft bus structure testing almost complete, about to head into propulsion I&T.
- Flight Cryocooler Compressor Assembly (CCA) in final testing stage at JPL and proceeding per plan.
- New horizontal shaker table complete at GSFC, working with vendor resolve vertical shaker table issue .
- Sunshield/Spacecraft are the critical path at 7.5 months of margin with 31 months to go.

# JWST Top Level Schedule

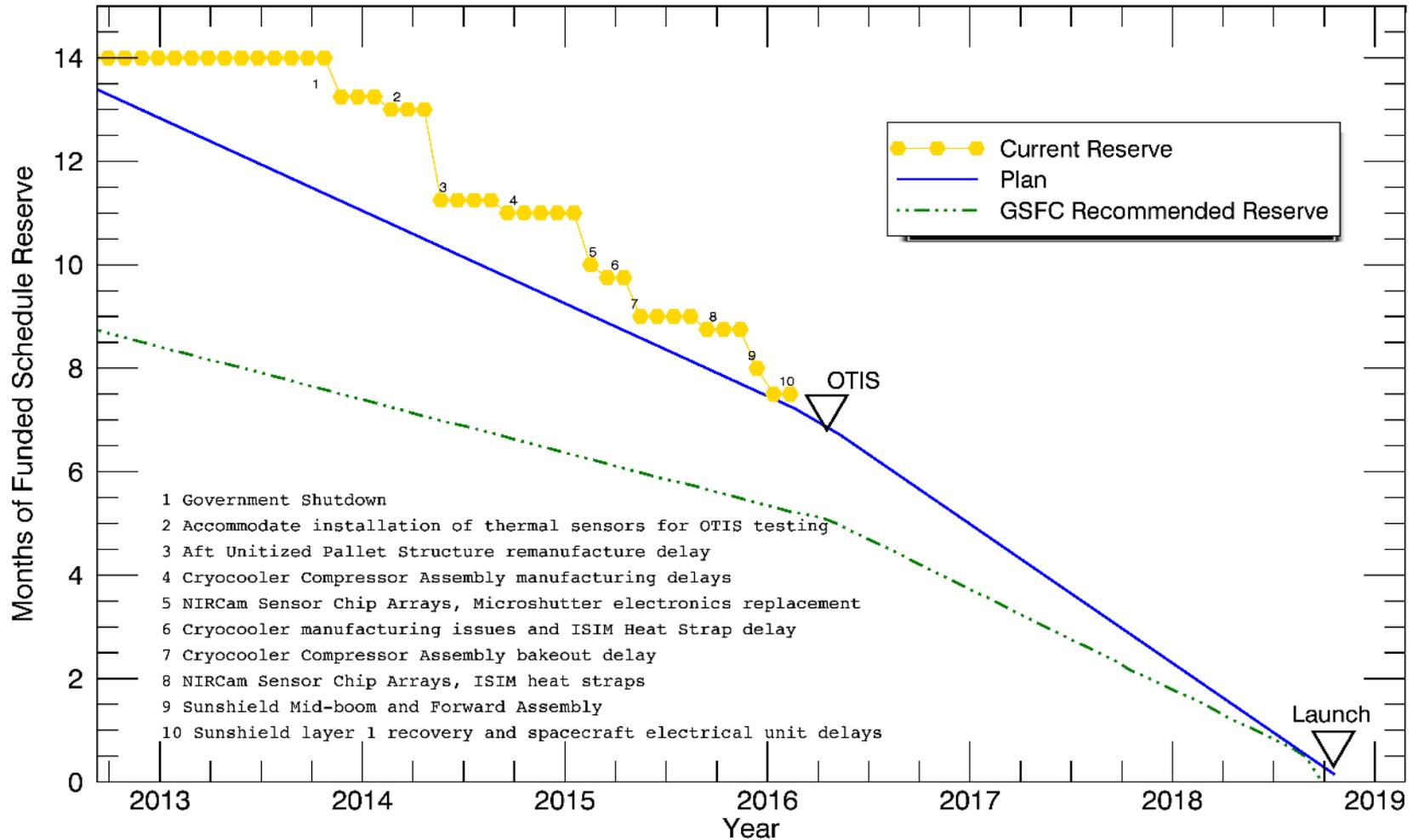


**k** months of project funded critical path (mission pacing) schedule reserve

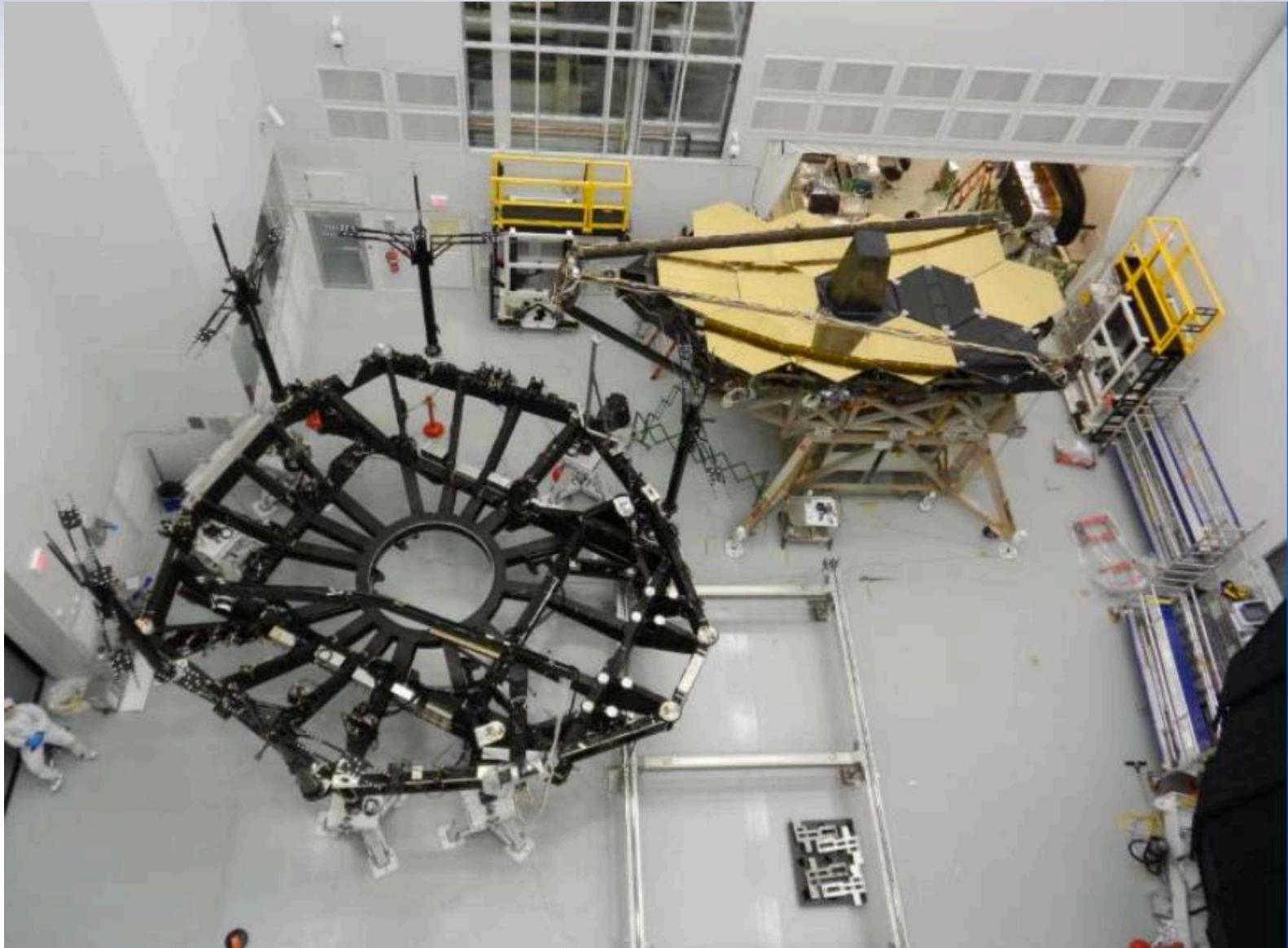


<span style="color: blue;">■</span>	Northrop-Grumman
<span style="color: cyan;">■</span>	Goddard Space Flight Center
<span style="border: 1px solid black; display: inline-block; width: 10px; height: 10px;"></span>	Johnson Space Center
<span style="color: maroon;">■</span>	Guiana Space Center

# JWST Funded Schedule Reserve



# JSC: Next Major Test Preparations



# JWST Hardware Progress



Integrated Science Instrument Module (ISIM) post CV3



Optical Telescope Element  
All Mirrors (PMSAs) Installed

JWST remains on track for an October 2018 launch within its replan budget guidelines

<http://jwst.nasa.gov/webcam.html>

# James Webb Space Telescope Summary



- While challenges are arising during final manufacturing and I&T phases:
  - We continue careful monitoring of FY16 UFE and now FY17 UFE,
  - Assembly of the Telescope is almost complete,
  - The MIRI Flight Cryocooler Compressor Assembly at JPL for testing continues to proceed nominally,
  - Good progress is being made on plan for the spacecraft,
  - OTIS integration and testing has entered an important phase, and
  - Must preserve schedule reserve for future challenges
- JWST team continues to execute to our LRD commitments

# Euclid

A visible and near-infrared telescope to explore cosmic evolution



## CURRENT STATUS:

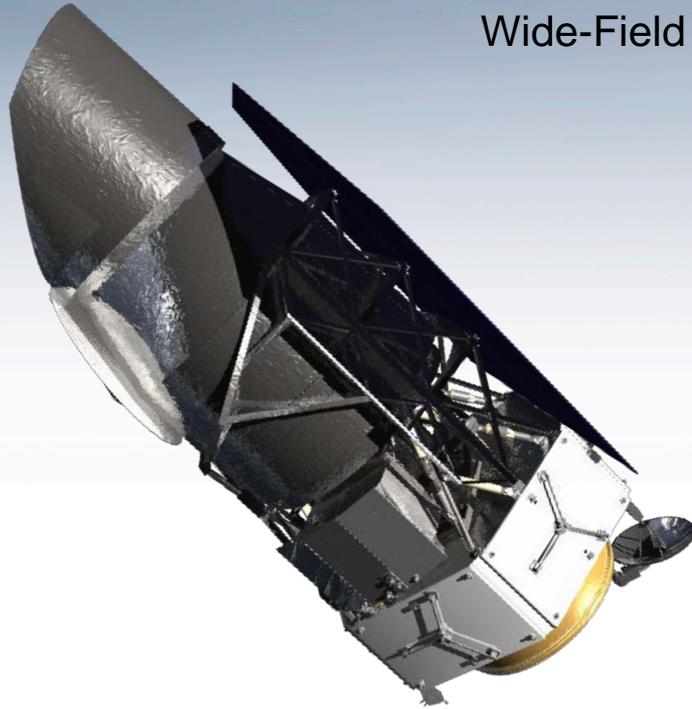
- Currently in implementation phase.
- ~60 U.S. scientists are members of the Euclid Science Team that will analyze the data, and make maps of the sky.
- The qualification detectors from the detector vendor are currently being tested at GSFC's Detector Characterization Lab, and JPL has taken delivery of the first flight detectors.
- NASA has all contracts in place for detector fabrication.
- NASA replan was completed on February 26, 2016 which has the first flight detectors being delivered to ESA in March 2017.
  - ENSCI formally made part of the project - provides US science node; reserves augmented to improve risk posture.

- **ESA Cosmic Vision 2015-2025 Mission, M-Class with NASA participation.**
- 1.2-m mirror, visible & near-IR images, spectra
- **Launch Date:** December 2020
- **Science Objectives:**
  - Euclid will look back 10 billion years into cosmic history.
  - Probe the history of cosmic expansion (influenced by dark energy and dark matter) and how gravity pulls galaxies together to form the largest structures.
  - The shapes of distant galaxies appear distorted because the gravity of dark matter bends their light (gravitational lensing). Measuring this distortion tells us how the largest structures were built up over cosmic time.
  - Measuring how strongly galaxies are clumped together tells us how gravity influences their motions, and how dark energy has affected the cosmic expansion.

<http://sci.esa.int/euclid/>

# WFIRST

## Wide-Field Infrared Survey Telescope



### CURRENT STATUS:

- Completed Mission Concept Review (MCR) held in December 2015
- Formulation Science Investigation Teams selected in December 2015; first meeting held February 2016.
- Passed Key Decision Point A (KDP-A) in Feb 2016
  - Official start of formulation phase
  - Supported by FY16 appropriation and FY17 request
  - Developed and signed Formulation Authorization Document (FAD), Project Formulation Agreement (PFA), and preliminary Program Level Requirements Appendix (PLRA).
  - Successful KDP-A DPMC held January 26, 2016.
  - Successful KDP-A APMC held February 17, 2016.
- Schedule under revision to account for FY16 appropriation of \$90M and FY17 budget request of \$90M. Notional runout of FY17 budget request provides in-guide budget supporting launch in mid-2020s.

### Wide-Field Infrared Survey Telescope

Top priority of 2010 Decadal Survey

**Science themes:** Dark Energy, Exoplanets, Large Area Near Infrared Surveys

**Mission:** 2.4m widefield telescope at L2; using existing hardware, images  $0.28\text{deg}^2$  at  $0.8\text{-}2\mu\text{m}$

### Instruments (design reference mission):

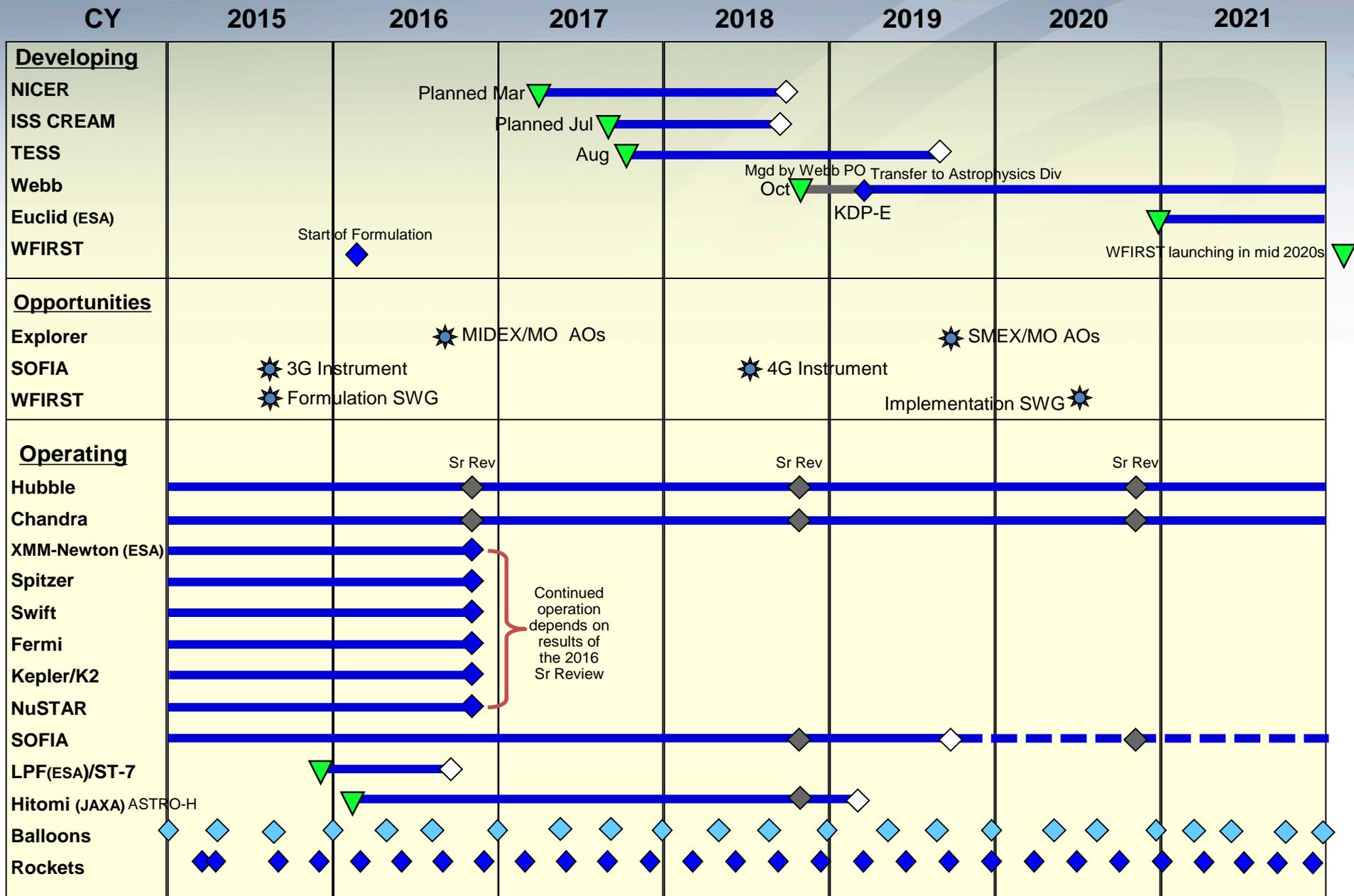
Wide Field Instrument (camera plus IFU), Coronagraph Instrument (imaging/IFS)

**Phase:** Currently in Formulation (Phase A)

APS Update by  
Neil Gehrels (GSFC)

# Astrophysics Science Mission Events

Last updated: February 22, 2016



▼ Launch Date (mission 'working to' date)    
 ◆ Event Date    
 ◇ End of Prime Mission    
 ◆ Balloon Campaigns    
 ★ AO Release (future is notional)

# FY16 Appropriation



Outyears are notional planning from FY16 President's budget request

(\$M)	2014	2015	2016	2017	2018	2019	2020
Astrophysics*	\$678	\$685	\$731	\$707	\$750	\$986	\$1118
JWST	\$658	\$645	\$620	\$569	\$535	\$305	\$198
Total	\$1336	\$1330	\$1351	\$1273	\$1285	\$1291	\$1316

\* Excludes "SMD STEM Activities" in all years.

- Provides \$90M for WFIRST and directs NASA to start Formulation.
- Provides full funding (\$85M) for SOFIA operations and places SOFIA into the 2018 Astrophysics Senior Review.
- Provides full funding (\$98M) for continued Hubble operations.
- Provides \$37M for SMD STEM education activities.
- Requires reduction of \$36M in rest of Astrophysics portfolio.

(\$M)	FY16 Request	FY16 Approps	Delta
JWST	\$620	\$620	--
WFIRST	\$14	\$90	+\$76
SOFIA	\$85	\$85	--
Hubble	\$97	\$98	+\$1
Rest of Astrophys*	\$493	\$457	-\$36 (-7%)
Total	\$1309	\$1351	+\$42

\* Excludes "SMD STEM Activities."

# FY17 Budget Request



	<b>Astrophysics</b>	<b>JWST</b>	<b>STEM</b>	<b>Astrophysics including JWST excluding STEM</b>	<b>Astrophysics including JWST including STEM</b>
FY16 appropriation	\$731M excluding STEM	\$620M	\$37M	\$1351M	\$1388M
FY17 notional runout of FY16 request	\$727M including STEM	\$569M	\$20M	\$1276M	\$1296M
FY17 request	\$782M including STEM	\$569M	\$25M	\$1326M	\$1351M

# FY17 Budget Request

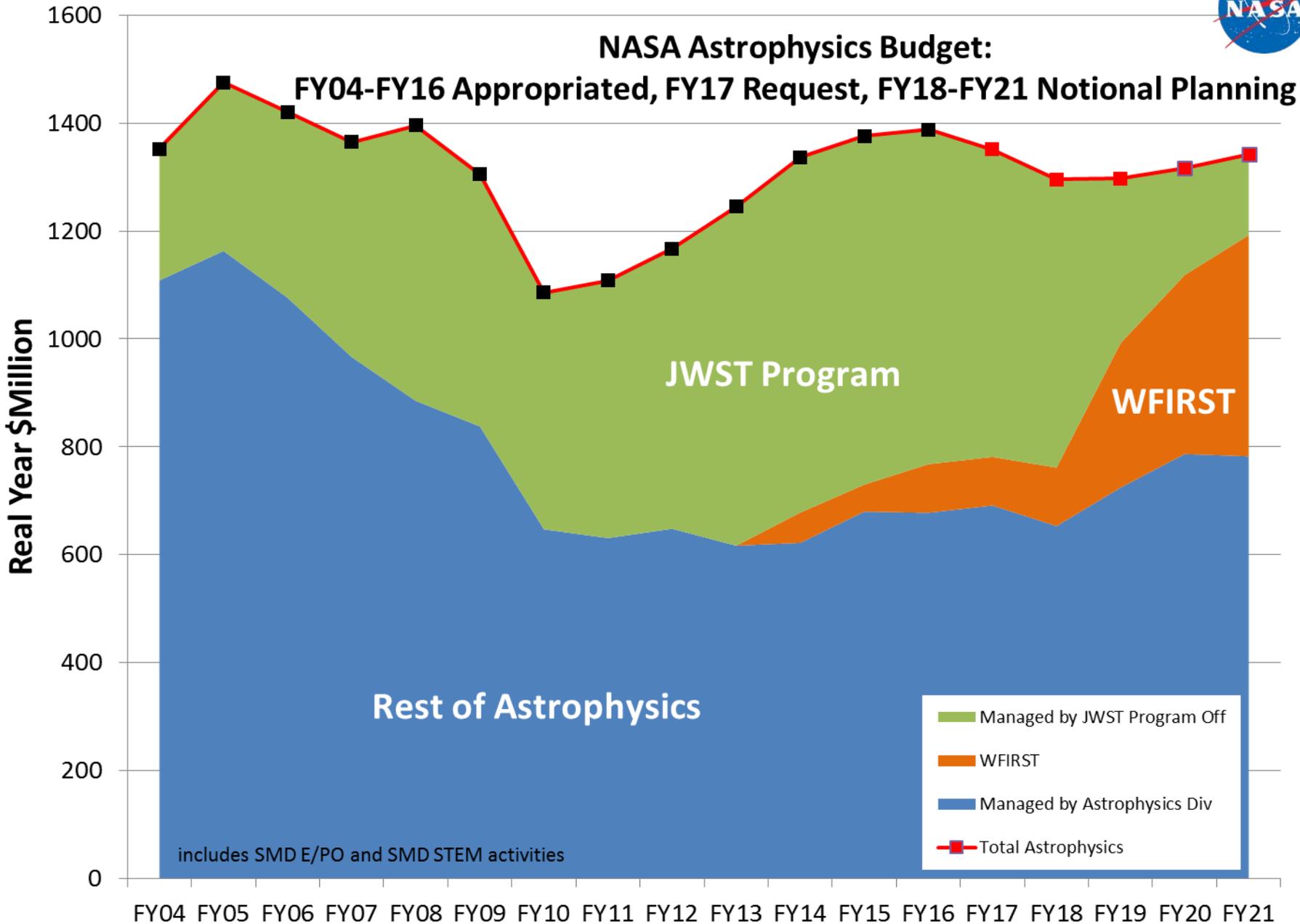


Outyears are notional planning from FY17 budget request

(\$M)	2015	2016	2017	2018	2019	2020	2021
Astrophysics*	\$685	\$731	\$757	\$737	\$967	\$1094	\$1168
JWST	\$645	\$620	\$569	\$534	\$305	\$197	\$150
Total*	\$1330	\$1351	\$1326	\$1271	\$1272	\$1291	\$1318

\* Excludes “SMD STEM Activities” in all years.

- This budget request is an excellent budget request for NASA Astrophysics (\$1,326M excluding STEM).
- It compares well with the FY16 Appropriation (\$1,351M excluding STEM) and significantly exceeds the FY17 notional runout in the President’s FY16 request for NASA Astrophysics including JWST (\$1,276M excluding STEM).
- This budget request and the notional runout allows WFIRST to be executed without additional funding.
- This budget request and the notional runout support other Decadal Survey priorities.
  - Continued Explorer AOs at the cadence of 4 per decade.
  - Partnerships on ESA’s Athena X-ray observatory and L3 gravitational wave observatory.
  - Precursor exoplanet science and technology including Large Binocular Telescope Interferometer, Extreme Precision Doppler Spectrometer, and WFIRST Coronagraph.
  - Retains prior growth in R&A and suborbital programs.
- Senior Review funding may be inadequate to continue all currently operating missions.
  - FY16 budget for Six Senior Review missions is \$62M. FY17 Senior Review budget is \$37M.



# CY16 and FY17 Planned Accomplishments



- JAXA's **Hitomi** (nee ASTRO-H) mission launched (KDP-E) on February 17, 2016.
- **WFIRST** entered formulation (KDP-A) on February 17, 2016.
- The main panel of the **Astrophysics Senior Review** was held February 2016. The **Fermi Gamma-ray Space Telescope, Kepler/K2, Nuclear Spectroscopic Telescope Array (NuSTAR), Spitzer Space Telescope, Swift Explorer, and XMM-Newton** were reviewed.
- The **Astrophysics Senior Review** for the **Hubble Space Telescope** and **Chandra X-ray Observatory** will be held in March 2016.
- NASA's ST7/DRS experiment on ESA's LPF will begin science operation in June 2016.
- **NICER** will be delivered to Kennedy Space Center by July 2016 and launched to the International Space Station (KDP-E) on CRS SpaceX-11 in FY17.
- Commissioning flights for the second-generation High-resolution Airborne Wideband Camera (HAWC+) instrument will be completed aboard **SOFIA** by August 2016.
- An Announcement of Opportunity (AO) for the next **Astrophysics Medium-Class Explorer (MIDEX)** and **Mission of Opportunity** will be released in FY16 [NET September 2016].
- The payload for **TESS** will be integrated and tested (KDP-D) by September 2016.
- The Step 2 downselect will be made for the next **Astrophysics Small Explorer (SMEX)** and **Explorer Mission of Opportunity** in FY17 [NET December 2016].
- The **ISS-CREAM** experiment will be launched to the International Space Station (KDP-E) on CRS SpaceX-12 in FY17.
- A critical design review for **SOFIA's** third-generation instrument will be conducted in FY17.
- Spacecraft integration and testing will be completed for **TESS** in FY17.
- **WFIRST** will have its System Requirements Review (KDP-B) in FY17.
- Four **Balloon** campaigns are planned in FY16, and four campaigns are planned in FY17.
- Four Astrophysics **Sounding Rocket** payloads have been successfully launched in FY16, and at least two are planned in FY17.

# Progress Toward Decadal Survey Priorities



## The NASA FY16 Appropriation, the President's FY17 Budget Request, and its notional out year budget planning guidance support:

Complete JWST	JWST remains within budget guidelines and on track for an October 2018 launch.
Large-scale 1. WFIRST	2 years of preformulation and focused technology development for WFIRST (a 2.4m version of WFIRST with a coronagraph) are complete. Formulation (new start) commenced in February 2016.
Large-scale 2. Augmentation to Explorer Program	Astrophysics Explorers planned budget increased to support cadence of four AOs per decade including a SMEX AO in Fall 2014 and a MIDEX AO in Fall 2016.
Large-scale 3. LISA	Planning partnership on ESA's L3 gravitational wave observatory and participating in ESA-led assessments in 2014-2015. Strategic astrophysics technology investments plus support of LISA Pathfinder. Established L3 Study Team.
Large-scale 4. IXO	Planning a partnership on ESA's L2 Athena X-ray observatory; the Athena study phase, with U.S. participation, is underway. Strategic astrophysics technology investments.
Medium-scale 1. New Worlds Technology Development Program	Focused technology development for coronagraph on WFIRST, strategic astrophysics technology investments, exoplanet probe mission concept studies. Partnership with NSF to develop precision Doppler spectrometer as facility instrument. Exozodi survey using LBTI.

# Progress Toward Decadal Survey Priorities



## The NASA FY16 Appropriation, the President's FY17 Budget Request, and its notional out year budget planning guidance support:

Medium-scale 2. Inflation Probe Technology Development	Balloon-borne investigations plus strategic astrophysics technology investments. Studying partnership on JAXA's LiteBIRD.
Small-scale. Research Program Augmentations	Increased annual R&A budget by 10% from FY10 to FY12 and another 10% from FY14 to FY16. Within R&A: established Theoretical and Computational Astrophysics Networks program with NSF; funding available for astrophysics theory; funding available for lab astrophysics; funding available for suborbital payloads.
Small-scale. Intermediate Technology development Augmentation	Established competed Strategic Astrophysics Technology program element; directed technology funding for WFIRST and other large-scale decadal priorities (e.g., WFIRST coronagraph, Athena detectors).
Small-scale. Future Ultraviolet-Visible Space Capability	Strategic Astrophysics Technology and Astrophysics R&A investments; mission concept studies.
Small-scale. SPICA (U.S. contribution to JAXA-led)	Not supported as a strategic contribution; candidate for Explorer Mission of Opportunity.

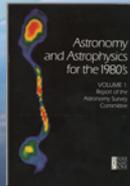
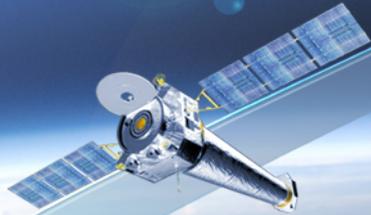


# ASTROPHYSICS

## Decadal Survey Missions



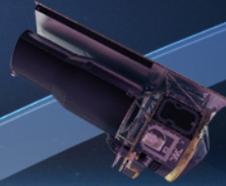
**1972**  
Decadal Survey  
*Hubble*



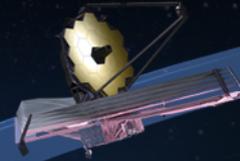
**1982**  
Decadal Survey  
*Chandra*



**1991**  
Decadal Survey  
*Spitzer, SOFIA*



**2001**  
Decadal Survey  
*JWST*



**2010**  
Decadal Survey  
*WFIRST*



# Preparing for the 2020 Decadal Survey Large Mission Concepts



NASA has begun to study large mission concepts as input to the 2020 Decadal Survey

- STDTs have a significant role and responsibility
  - Develop science case
  - Flow science case into mission parameters
  - Vet technology gap list
  - Direct trades of science vs cost/capability
- STDT members appointed by NASA HQ
- STDTs chartered by HQ and administered through the Program Offices
  - Charter and management plan available at:  
<http://science.nasa.gov/astrophysics/2020-decadal-survey-planning/>

# Decadal Survey Concept Study Deliverables



All products delivered to APD Deputy Division Director

M1	Comments on Study Requirements and Deliverables	April 29 2016 <sup>1</sup>
	<ul style="list-style-type: none"><li>– Accept the study requirements/deliverables and submit plan--- or</li><li>– Provide rationale for modifying requirements/deliverables</li></ul>	
<b>O1</b>	<b>Optional: Initial Technology Gap Assessment</b>	June 30 2016
	<ul style="list-style-type: none"><li>– To impact PCOS/COR/ExEP 2016 technology cycle</li></ul>	
M2	Detailed Study Plan	August 26 2016
	<ul style="list-style-type: none"><li>– Document starting point CML</li><li>– Deliver detailed study plan for achieving Decadal CML</li><li>– Deliver resource required to meet the deliverables for the study duration</li><li>– Deliver schedule to deliver milestones</li></ul>	
<b>M3</b>	<b>Complete Concept Maturity Level 2 Audit</b>	February 2017 <sup>2</sup>
	<ul style="list-style-type: none"><li>– Identify, quantify and prioritize technology gaps for 2017 technology cycle</li></ul>	
<b>O2</b>	<b>Optional: Update Technology Gap Assessments</b>	June 2017
<b>M4</b>	<b>Interim Report</b>	Early Dec 2017 <sup>2</sup>
	<ul style="list-style-type: none"><li>– Substantiate achieving Concept Maturity Level 3</li><li>– Deliver initial technology roadmaps; estimate technology development cost/schedule</li></ul>	
M5	Update Technology Gap Assessments	June 2018
	<ul style="list-style-type: none"><li>– In support of 2018 technology cycle</li></ul>	
M6	Complete Decadal Concept Maturity Level 4 Audit and Freeze Point Design	August 2018
	<ul style="list-style-type: none"><li>– Support independent cost estimation/validation process</li></ul>	
M7	Final Report	January 2019
	<ul style="list-style-type: none"><li>– Finalize technology roadmaps, tech plan and cost estimates for technology maturity</li></ul>	
M8	Submit to Decadal	March 2019

<sup>1</sup> APD will provide final study requirements by May 2016

<sup>2</sup> Timed to influence following NASA budget cycle

# Preparing for the 2020 Decadal Survey Large Mission Concepts



NASA is initiating community-led studies of the following four large mission concepts.

	Community STDT Chairs	Center Study Scientist	Study Lead Center	HQ Program Scientist
Far IR Surveyor	Asantha Cooray Margaret Meixner	David Leisawitz	GSFC	Kartik Sheth
Habitable Exoplanet Imaging Mission	Scott Gaudi Sara Seager	Bertrand Mennesson	JPL	Martin Still
Large UV/Optical/IR Surveyor	Debra Fischer Bradley Peterson	Aki Roberge	GSFC	Mario Perez
X-ray Surveyor	Feryal Ozel Alexey Vikhlinin	Jessica Gaskin	MSFC	Dan Evans

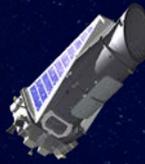
APS Update by

D. Leisawitz (GSFC), B. Mennesson (JPL), A. Roberge (GSFC), J. Gaskin (MSFC)

■	Formulation
■	Implementation
■	Primary Ops
■	Extended Ops



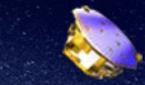
Spitzer  
8/25/2003



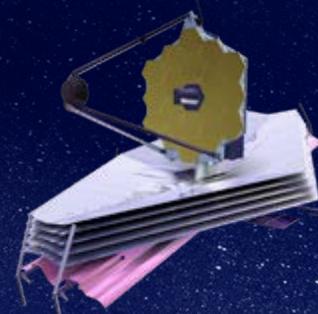
Kepler  
3/7/2009



WFIRST  
Mid 2020s



LISA Pathfinder (ESA)  
12/3/2015



JWST  
2018



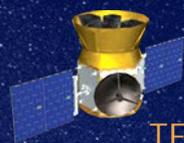
Euclid (ESA)  
2020



Chandra  
7/23/1999



XMM-Newton (ESA)  
12/10/1999



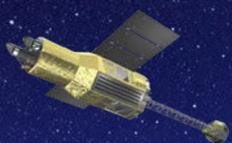
TESS  
2017



NuSTAR  
6/13/2012



Swift  
11/20/2004



Hitomi (JAXA)  
2/17/2016



Fermi  
6/11/2008



Hubble  
4/24/1990



CREAM (on ISS)  
2017

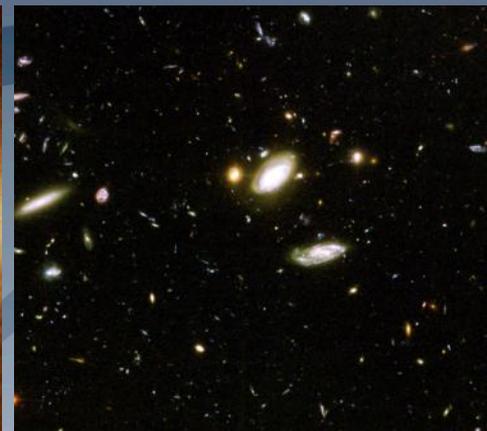


NICER (on ISS)  
2017



SOFIA  
Full Ops 5/2014

# Astrophysics



BACKUP

# Astrophysics Program Content



	Actual	Enacted	Request	Notional			
	<u>FY 2015</u>	<u>FY 2016</u>	<u>FY 2017</u>	<u>FY 2018</u>	<u>FY 2019</u>	<u>FY 2020</u>	<u>FY 2021</u>
<b>Astrophysics</b>	<b>730.7</b>		<b>781.5</b>	<b>761.6</b>	<b>992.4</b>	<b>1,118.6</b>	<b>1,192.5</b>
<u>Astrophysics Research</u>	<u>201.7</u>		<u>226.1</u>	<u>236.3</u>	<u>235.7</u>	<u>248.5</u>	<u>252.0</u>
Science Education	42.0		25.0	25.0	25.0	25.0	25.0
Astrophysics Research and Analysis	71.1		72.7	73.0	73.0	73.0	73.0
Balloon Project	38.0		37.0	37.3	37.4	38.9	40.4
<u>Other Missions and Data Analysis</u>	<u>50.6</u>		<u>91.4</u>	<u>101.0</u>	<u>100.3</u>	<u>111.6</u>	<u>113.6</u>
Astrophysics Data Curation and Archival	18.6		17.8	18.8	18.9	18.9	18.9
Astrophysics Data Program	17.0		17.6	17.6	17.6	17.6	17.6
Astrophysics Senior Review	-		37.4	49.3	40.5	33.6	34.0
Contract Administration, Audit & QA Svcs	15.0		14.9	15.0	15.0	15.1	15.1
Astrophysics Directed R&T	-		3.7	0.2	8.4	26.4	28.1
<u>Cosmic Origins</u>	<u>201.0</u>		<u>198.5</u>	<u>198.4</u>	<u>197.3</u>	<u>195.5</u>	<u>209.5</u>
Hubble Space Telescope (HST)	98.6		97.3	98.3	98.3	98.3	98.3
Stratospheric Observatory for Infrared Astronom	70.0		83.8	84.8	84.8	84.8	84.8
<u>Other Missions and Data Analysis</u>	<u>32.4</u>		<u>17.4</u>	<u>15.3</u>	<u>14.2</u>	<u>12.4</u>	<u>26.4</u>
Cosmic Origins Future Missions	1.2		1.1	1.5	1.5	1.5	1.5
Spitzer	14.6		3.5	-	-	-	-
Herschel	5.1		1.0	-	-	-	-
Cosmic Origins SR&T	8.8		9.3	10.9	9.8	8.0	22.0
Cosmic Origins Program Management	2.6		2.5	2.9	2.9	2.9	2.9

# Astrophysics Program Content (cont'd)



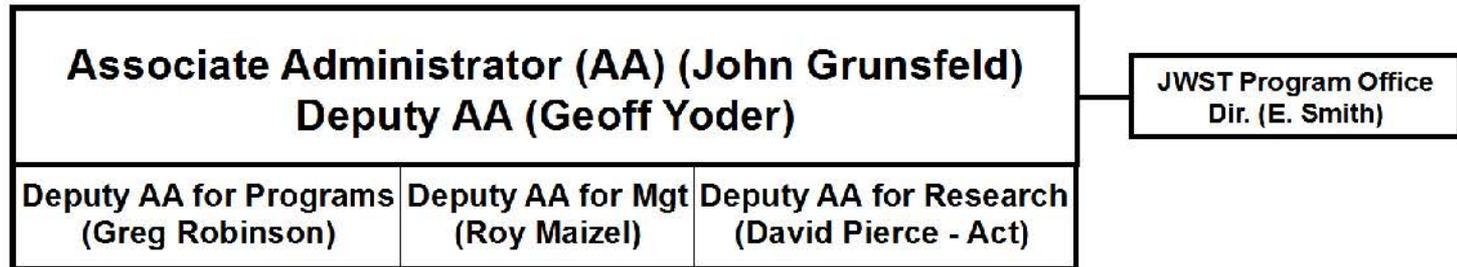
	Actual	Enacted	Request	Notional			
	<u>FY 2015</u>	<u>FY 2016</u>	<u>FY 2017</u>	<u>FY 2018</u>	<u>FY 2019</u>	<u>FY 2020</u>	<u>FY 2021</u>
<u>Physics of the Cosmos</u>	<u>104.1</u>		<u>94.1</u>	<u>88.0</u>	<u>94.1</u>	<u>97.7</u>	<u>94.0</u>
Physics of the Cosmos Future Missions	0.1		0.5	2.1	2.1	2.5	2.5
Euclid	7.5		12.9	7.5	7.7	9.9	6.1
Chandra X-Ray Observatory	55.6		52.4	56.7	57.4	58.4	58.4
Fermi Gamma-ray Space Telescope	16.9		-	-	-	-	-
XMM	2.9		-	-	-	-	-
Planck	6.0		-	-	-	-	-
Physics of the Cosmos SR&T	12.0		25.4	18.5	23.7	23.8	23.9
Physics of the Cosmos Program Management	3.0		2.9	3.2	3.2	3.2	3.2
<u>Exoplanet Exploration</u>	<u>100.6</u>		<u>133.8</u>	<u>148.0</u>	<u>309.3</u>	<u>373.3</u>	<u>450.8</u>
Decadal Strategic Mission (WFIRST)	50.0		90.0	108.2	267.7	331.8	409.9
Exoplanet Exploration Future Missions	0.9		0.5	1.1	8.2	8.3	8.3
Kepler	17.2		2.8	-	-	-	-
Keck Operations	6.0		6.1	6.2	-	-	-
Large Binocular Telescope Interferometer	2.0		1.3	-	-	-	-
Exoplanet Exploration SR&T	19.4		28.0	26.5	27.6	26.9	26.2
Exoplanet Exploration Program Management	5.1		5.1	6.0	5.9	6.3	6.4

# Astrophysics Program Content (cont'd)

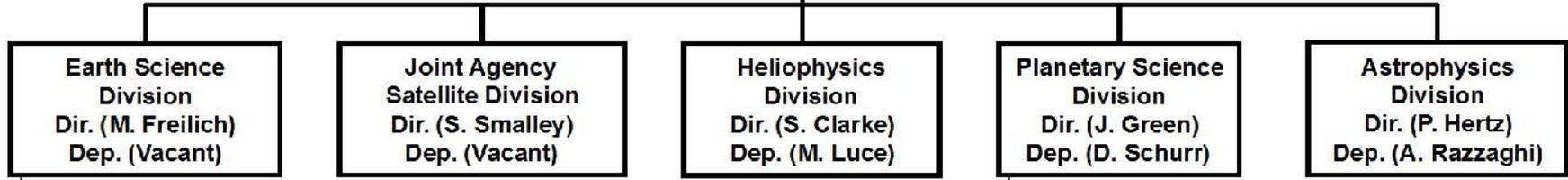
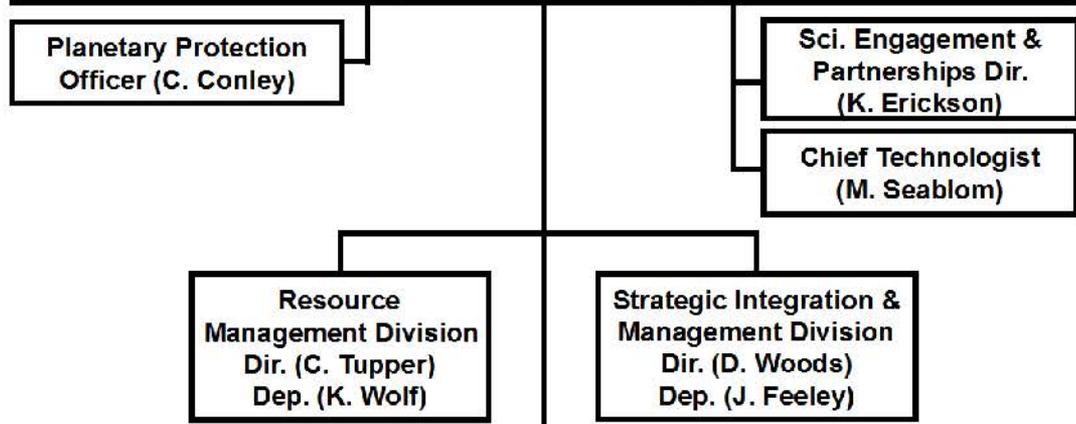


	Actual	Enacted	Request	Notional			
	<u>FY 2015</u>	<u>FY 2016</u>	<u>FY 2017</u>	<u>FY 2018</u>	<u>FY 2019</u>	<u>FY 2020</u>	<u>FY 2021</u>
<u>Astrophysics Explorer</u>	<u>123.3</u>		<u>129.0</u>	<u>91.0</u>	<u>156.0</u>	<u>203.5</u>	<u>186.2</u>
Transiting Exoplanet Survey Satellite (TESS)	80.1	73.5	87.0	27.9	9.1	2.5	0.0
<u>Other Missions and Data Analysis</u>	<u>43.2</u>		<u>42.0</u>	<u>63.1</u>	<u>146.9</u>	<u>201.1</u>	<u>186.2</u>
Astrophysics Explorer Future Missions	1.1		16.8	42.7	132.2	192.6	178.5
ASTRO-H (SXS)	11.3		12.0	11.4	9.5	-	-
NICER	11.7		3.5	1.3	-	-	-
Nuclear Spectroscopic Telescope Array	7.4		-	-	-	-	-
Swift	4.9		-	-	-	-	-
Suzaku (ASTRO-E II)	0.6		-	-	-	-	-
Astrophysics Explorer Program Management	6.2		9.8	7.7	5.1	8.5	7.7
<b>James Webb Space Telescope</b>	<b>645.4</b>	<b>620.0</b>	<b>569.4</b>	<b>533.7</b>	<b>304.6</b>	<b>197.2</b>	<b>149.8</b>
<b>Astrophysics + Webb Total</b>	<b>1,376.1</b>		<b>1,350.9</b>	<b>1,295.3</b>	<b>1,297.0</b>	<b>1,315.8</b>	<b>1,342.3</b>

# SMD Organization Chart



- Embeds/POCs**
- Chief Engineer (J. Pellicciotti)
  - Safety & Msn Assurance (P. Panetta)
  - General Counsel (M. Harrington)
  - Legislative & Intergvtl Affairs (G. Adler)
  - Public Affairs (D. Brown)
  - Intl & Interagency Relations (D. McSweeney)



- Flight (E. Ianson)
- Applied Sciences (L. Friedl)
- Research (J. Kaye)
- Technology (GSFC) (G. Komar)

- Solar System Expl (D. Schurr - Act)
- Mars Exploration (J. Watzin)
- Research (J. Rall)

# Astrophysics Division, Science Mission Directorate



**Resource Management**  
 Omana Cawthon+  
 Clemencia Gallegos-Kelly+

**Director**  
 Paul Hertz

**Deputy Director**  
 Andrea Razzaghi

*Lead Secretary:* Kelly Johnson  
*Secretary:* Leslie Allen  
*Program Support Specialist:* Jackie Mackall

**Cross Cutting**  
*Technology Lead:* Billy Lightsey\*  
*Division E/PO POC:* Hashima Hasan (Lead Comm Team)  
*Division Public Affairs POC:* Kartik Sheth  
*Information Manager:* Lisa Wainio\*

**Astrophysics Research**

*Program Manager:* Linda Sparke  
*Program Support:* Pam Terrell\*

Astrophysics Data Analysis: Doug Hudgins  
 Astrophysics Theory: Keith MacGregor\*  
 Exoplanet Research: Martin Still\*  
     APRA lead: Michael Garcia\*

Cosmic Ray, Fund Physics: Thomas Hams\*, Vernon Jones,  
 Keith MacGregor\*, Rita Sambruna  
     Gamma Ray/X-ray: Dan Evans, Michael Garcia\*, Stefan  
     Immler\*, Lou Kaluzienski, Rita  
     Sambruna, Wilt Sanders  
     Optical/Ultraviolet: Michael Garcia\*, Hashima Hasan,  
     Mario Perez\*, Martin Still\*

IR/Submillimeter/Radio: Dominic Benford\*, Doug Hudgins,  
 Kartik Sheth, Erin Smith\*

    Lab Astro: Doug Hudgins  
     Theory & Comp Astro Net: Keith MacGregor\*  
     Roman Tech Fellows: Billy Lightsey\*  
     Data Archives: Hashima Hasan  
 Astrophys Sounding Rockets: Wilt Sanders  
     Balloons Program: Vernon Jones(PS), Mark Sistilli (PE)

**Programs / Missions & Projects**

	<i>Program Scientist</i>	<i>Program Executive</i>
<b>Exoplanet Exploration (EXEP)</b>		
<b>Program</b>	<b>Doug Hudgins</b>	<b>John Gagosian</b>
Keck	Hashima Hasan	Mario Perez*
Kepler/K2	Mario Perez*	Keith Chamberlin/Jeff Hayes
LBTI	Hashima Hasan	Mario Perez*
NExScI	Hashima Hasan	Mario Perez*
NN-EXPLORE	Doug Hudgins	John Gagosian
WFIRST	Dominic Benford*	John Gagosian
<b>Cosmic Origins (COR)</b>		
<b>Program</b>	<b>Mario Perez*</b>	<b>Shahid Habib*</b>
Herschel	Dominic Benford*	Jeff Hayes
Hubble	Michael Garcia*	Jeff Hayes
JWST	Hashima Hasan	Ray Taylor^
SOFIA	Hashima Hasan	Shahid Habib*
Spitzer	Erin Smith*	Jeff Hayes
<b>Physics of the Cosmos (PCOS)</b>		
<b>Program</b>	<b>Rita Sambruna</b>	<b>Shahid Habib*</b>
Athena	Michael Garcia*	Jeanne Davis
Chandra	Stefan Immler*	Jeff Hayes
Euclid	Linda Sparke	Keith Chamberlin*
Fermi	Keith MacGregor*	Jeff Hayes
Planck	Rita Sambruna	Jeff Hayes
ST-7/LPF	Rita Sambruna	Keith Chamberlin*
XMM-Newton	Stefan Immler*	Jeff Hayes
<b>Astrophysics Explorers (APEX)</b>		
<b>Program</b>	<b>Wilt Sanders</b>	<b>Jeanne Davis</b>
ASTRO-H	Lou Kaluzienski	Jeanne Davis
NICER	Rita Sambruna	Jeanne Davis
NuSTAR	Lou Kaluzienski	Jeff Hayes
Suzaku	Stefan Immler*	Jeff Hayes
Swift	Martin Still*	Jeff Hayes
TESS	Doug Hudgins	Mark Sistilli

+ Member of the Resources Mgmt Division  
 \* Detailee, IPA, or contractor  
 ^ JWST is part of the JWST Program Office.